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NATURAL HISTORY SURVEY
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STRIPED BASS

"The Basse is one of the best fishes in the country . . . the way to catch them is with hooke and line: the Fisherman taking a great codline, to which he fasteneth a piece of Lobster, and throws it into the sea, the fish biting at it he pulls her to him, and knocks her on the head with a sticke . . . the English at the top of an high water doe crosse the creeks with long seanes or Basse netts, which stop in the fish; and the water ebbing from them they are left on dry ground, sometimes two or three thousand at a set . . ."

From William Wood, New England's Prospect (1635)

This fish, of the sea bass family Serranidae, with scientific name *Roccus saxatilis* (Walbaum) and common name "Striped Bass" and "Rock" or "Rockfish," is still one of the most valuable anadromous fishes on the coasts of North America. Although the species is distributed from the St. Lawrence River, Canada, to St. Johns River, Fla., and in tributary streams of the Gulf of Mexico from western Florida to Louisiana on the Atlantic Coast, it is most abundant in Chesapeake Bay. In 1879 and 1881, a number of yearling fish were seined in New Jersey, taken across the continent in tanks by train, and planted in San Francisco Bay, where they prospered and now occur from southern California to Washington. A landlocked population was established with the impounding of Santee-Cooper Reservoir in South Carolina; however, attempts to establish the species in other fresh-water impoundments have had only limited success.

Its high-quality, white, flaky flesh is in high demand as a food, and a substantial commercial fishery has existed since colonial days. At the same time, its voracious predatory feeding habits places it in high demand as a game fish that is avidly sought by a large and growing group of anglers.

Easily Recognized

Striped Bass more than 4 inches long would hardly be confused with any other species on the Atlantic or Pacific Coasts; however, where introduced into Mississippi and Ohio Valleys, it could be confused with the fresh-water species of Yellow Bass and White Bass, *Roccus mississippiensis* and *R. chrysops.* Its prominent dark longitudinal stripes, general outline, and fin structure are sufficient to separate it at a glance from other species. The seven or eight dark stripes, much the same olive-green color as the back, usually parallel the rows of scales three or four above the lateral line, one invariably on the lateral line, and three below it. Dorsal fins are clearly separate, not touching at the base. The body is elongate and little compressed, with the contour of the back little arched.

Historically Important

Striped Bass ranks close to the immortal Codfish in the vital part which our fishery resources played in early American history. Together, they were probably the first natural resources in colonial America subject to conservation measures enacted by statute — the General Court of Massachusetts Bay Colony in 1639 ordered that neither fish should be used as fertilizer for farm crops. The first public (free) school of the New World was made possible through monies derived, in part, from the sale of Striped Bass. A portion of the monies was also expended in helping widows and orphans of men formerly engaged in service to the Colony.

Early Decline in Abundance

Early settlers in New England were astonished by the abundance of this fish. Abundant as it may have seemed, however, its ease of capture made possible a

MARINE RESOURCES OF THE ATLANTIC COAST

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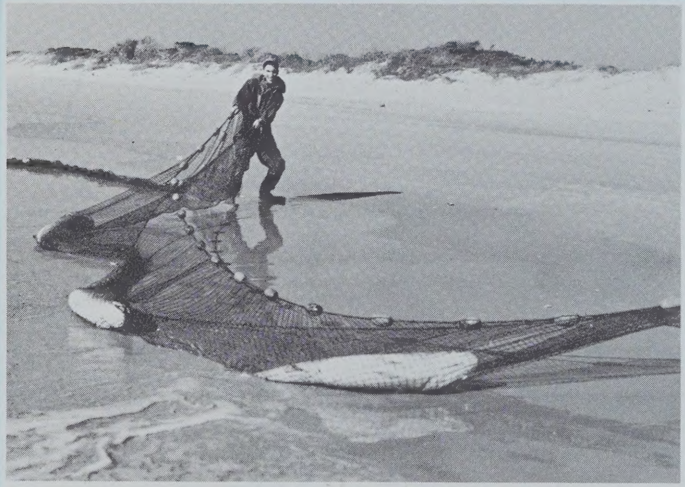
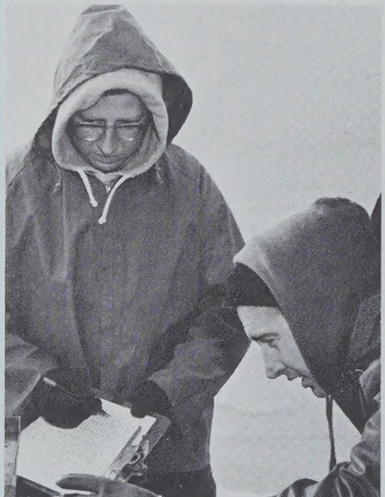
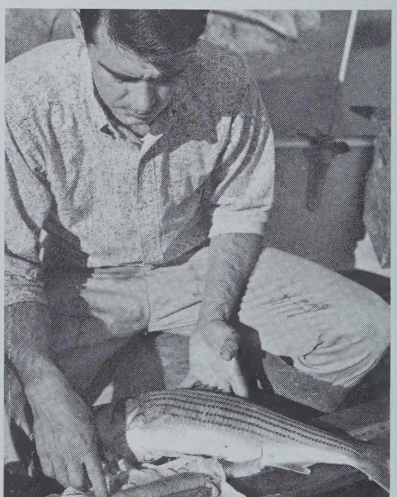
Educational Series No. 82

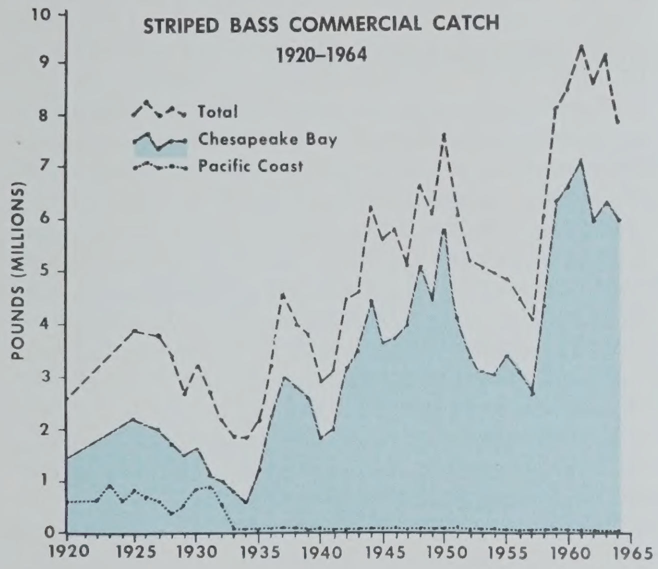
Commercial fishermen in North Carolina drifting a gill net for Striped Bass in the Roanoke River (upper left) and unloading a catch from Albemarle Sound (upper right). A series of three scenes (middle left and right, lower center) shows biologists beaching a haul seine on the Outer Banks of North Carolina and moving jumbo specimens for measuring and tagging. Other biological data are obtained from length and weight measurements — on specimens sampled from the gill net fishery in Chesapeake Bay, Maryland (lower left) — and by stripping the ovaries for a fecundity study (lower right).







decrease in supply over its northerly range. Although overfishing was probably the initial cause of this decline, construction of dams blocking access to spawning grounds and pollution in rivers played effective parts in the decrease of this species, as well as other anadromous food fish such as American Shad, Atlantic Salmon, and Sturgeon. A decline in the supply of Striped Bass in Chesapeake Bay was not as marked as in more northerly areas, probably because the bay had less industrial development and more limited population than the north. Nevertheless, smallest catches were noted in many sections of its more southerly range.


STRIPED BASS COMMERCIAL CATCH
1920–1964

Commercial Harvest is High

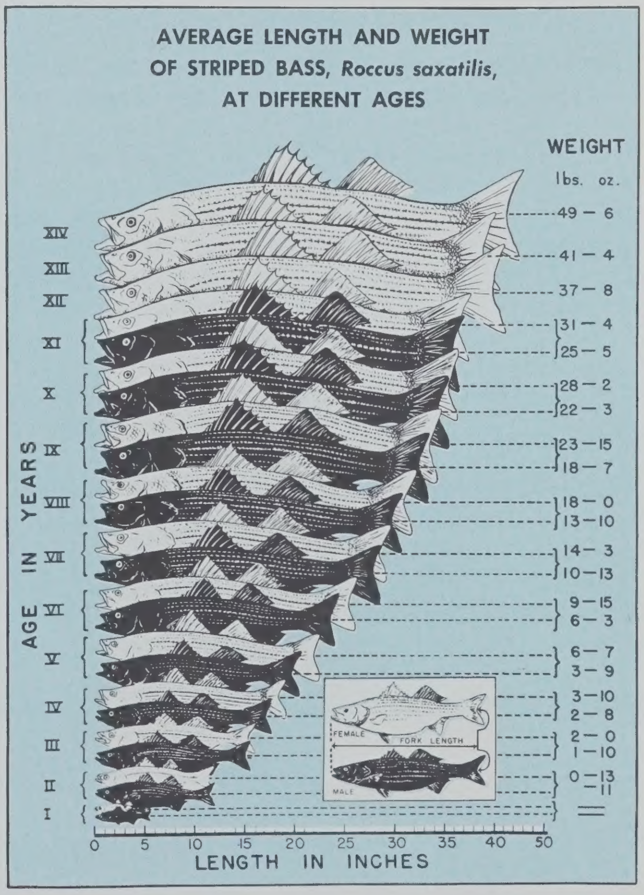
The supply of this fish has varied widely during the past 50 years and probably since its fishery began. Unfortunately, accurate catch records, which are the only means of estimating relative abundance in different periods, are not available for early years. Fortunately, the stocks have been high in recent years, and have supported large food and sport fisheries.

The commercial harvest along the Atlantic Coast has been increasing, with minor fluctuations, during the past 3 decades. Today the annual commercial catch is more than 8 million pounds worth about $1.5 million. Commercial fishing is geared mainly for 2- and 3-year-old fish, weighing from 1 to 2 pounds. Specimens over 60 pounds are seldom encountered; however, the record size is 125 pounds. Various gears used in the fishery include haul seines that take about 20 percent of the catch, pound nets 25 percent, gill nets 50 percent, fyke nets and miscellaneous gears 5 percent. Since 1963, the otter trawl winter fishery along the New Jersey coast has made substantial catches.

On the Pacific Coast, the supply of Striped Bass has increased many fold since its introduction. Prior to 1930, the commercial fishery yielded over 17 million pounds. In 1931, California declared it a sport species, and commercial netting was prohibited.

Recreational Use Important and Growing

Early historians noted that angling for Striped Bass was almost unexcelled and identified the species as the "boldest, bravest, strongest, and most active fish that visited tidal waters and bays along the Atlantic seaboard." Even today, its value to many areas is greater from a recreational than from a food standpoint. The sport catch is substantial but unrecorded, except in isolated instances. The U. S. Fish and Wildlife Service reports that sports fishermen took more than 9 million Striped Bass in tidal waters along the Atlantic coast in 1960. On the Pacific coast, the average annual catch is about 3 million fish, of which California produces more than 2 million. In Chesapeake Bay, the sport catch is about equal to the commercial catch. The sport catch is made by all types of fishermen from the highly specialized spin caster and troller to the less skilled but eager bait angler. From southern New Jersey to Cape Cod it is the unchallenged first choice of surfcasters.


AVERAGE LENGTH AND WEIGHT
OF STRIPED BASS, *Roccus saxatilis*,
AT DIFFERENT AGES

Biology Well Known

The species is anadromous, that is, it ascends rivers from March to July to spawn and may go upstream as far as 200 miles from salt water. During the spawning act, a single large female is surrounded by a few to many males. Spectacular "fights" then ensue, which are really courtship antics, and are accompanied by deposition of eggs. The number of eggs produced by each female varies with size: 14,000 by a 3-pounder female and nearly 5 million by a 50-pounder. The eggs hatch in about 2 days at a water temperature of 65° F. The young range in length from 3 to 6 inches at the end of the first year.

Striped Bass are voracious and carnivorous — they feed mostly on other fishes, but also take considerable quantities of invertebrates, especially crustaceans.

Females reach maturity in 4 or 5 years, at which time they weigh from 4 to 5 pounds. Most males are mature when 2 years old and all are mature at 3 years. The fish grow rapidly early in their life, but an increase in weight and length tapers off after the 10th year. The age of the fish is determined by counting the annual growth marks on their scales, as one tells the age of a tree by counting the rings in a cross section.

Striped Bass travel in large schools, especially after they are 2 years old. Tagging studies have shown that the fish are relatively inactive during the winter and congregate in deep pools near the river mouths and in bays and estuaries. In the spring, mature fish move into rivers and on upstream to spawn.

After spawning the mature fish move out of the rivers into open water for feeding through summer and fall. Certain segments of the Atlantic Coast stocks, primarily from the Hudson River and Chesapeake and Delaware Bays, leave their native areas and make coastal migrations. They move northward in late winter or early spring and congregate off the New England coast. These migrants remain in the New England area until autumn, when they move southward to their "home" area. There is evidence that Striped Bass return to their native stream to spawn.

Research and Management Essential

Effective management can only be built upon a thorough understanding of the biology of the Striped Bass and knowledge of the fisheries. Most States throughout the range of the species and the Fish and Wildlife Service are studying its life history, migration patterns, size of stocks, and causes of fluctuations in abundance. Management measures, based on such research, have been initiated by the States in an effort to use the resource more effectively. These include: minimum and maximum size limits, daily bag limits, control of the amount and type of gear and season of fishing, and pollution abatement. Attempts to propagate Striped Bass by means of hatcheries have never been successful, as operated, in increasing natural reproduction. Hatcheries for the species are in operation on the Roanoke River at Weldon, N. C., and Santee-Cooper River at Moncks Corner, S. C. Because there are a number of different management policies governing fishing, local State agencies should be consulted for details.

Wiser Management Possible

The present fisheries for Striped Bass are productive and essentially healthy; however, continuation of research is necessary to make available additional biological information on which to build a more effective management policy. The major problems now are changes in the environment resulting from water developments for hydroelectric power, navigation, and flood storage; increased domestic and industrial pollution entering rivers; and increased competition between sport and commercial fishermen. Striped Bass, as with other fishes, must be given an opportunity to survive. Wiser management toward conserving the species for the future is possible, but only through the coordinated efforts of local governments and society.

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AMERICAN SHAD . . . A SPRINGTIME DELICACY

Shad, like salmon, migrate thousands of miles in the ocean and return to their natal stream to spawn, but how and by what mechanism they are guided remains a mystery.

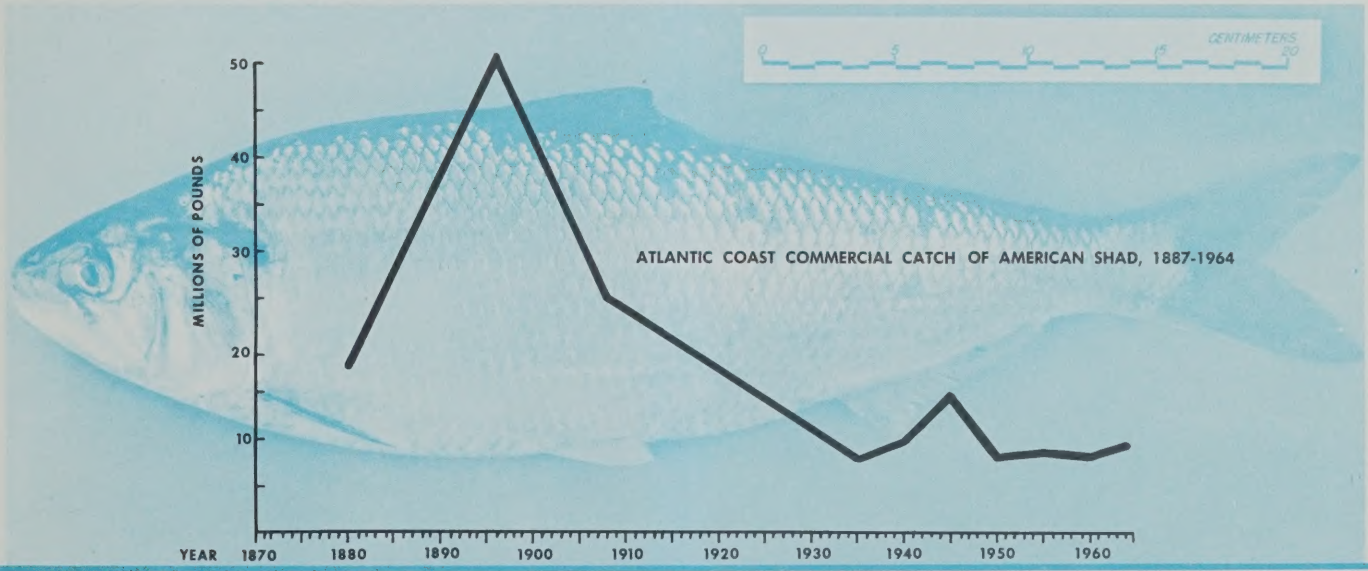
This fish, of the herring family Clupeidae, with the scientific name *Alosa sapidissima* (Wilson) and common names "White Shad," "Poplarback Shad," and just plain "Shad," is found throughout its range in sufficient quantities to give rise to fisheries of great economical and recreational values. The appearance of this fish in the fresh fish markets is a sure sign of spring. On the Atlantic Coast, it is distributed from the Gulf of St. Lawrence, Canada, to St. Johns River, Fla., and is most abundant from North Carolina to Connecticut. Many attempts to introduce the species in waters where it is not native, such as the Mississippi drainage and tributaries to the Great Lakes and Great Salt Lake, have failed. It was successfully introduced in the Sacramento and Columbia Rivers on the Pacific Coast in the 1870's and now occurs from the Mexican border to Cook Inlet, Alaska. Because little information is available on the Pacific Coast stocks, this report is primarily about the species on the Atlantic Coast.

Largest of the Clupeids

The species is the largest and best known of the clupeids in our waters — males average about 3 pounds and females about 4 pounds. Shad as large as 12 pounds have been reported, but one more than 6 pounds is seldom caught. This fish, like many clupeids, has compressed fusiform shape, single soft rayed back and anal fins, deeply forked tail fin, strongly serrated ventral edge of abdomen, large scales that are easily lost, and a row of dark spots behind the gill cover. A longer than deep cheek bone distinguishes it from the other fish such as Alewives or Hickory Shad with which it is frequently associated. Great difficulties are often experienced with young clupeids in discriminating between the various species.

Biology and Life History Well Known

This species is anadronous, spending most of its life in the ocean but ascending coastal rivers to spawn. The spawning migrations into the Atlantic Coast rivers begin earliest in the southern part of the range (November in St. Johns River, Fla.), and are progressively later northward (June in St. John River, Canada). Those that spawn in streams south of Chesapeake Bay, and particularly south of North Carolina, apparently die after spawning. Those that spawn in streams from Chesapeake



MARINE RESOURCES OF THE ATLANTIC COAST

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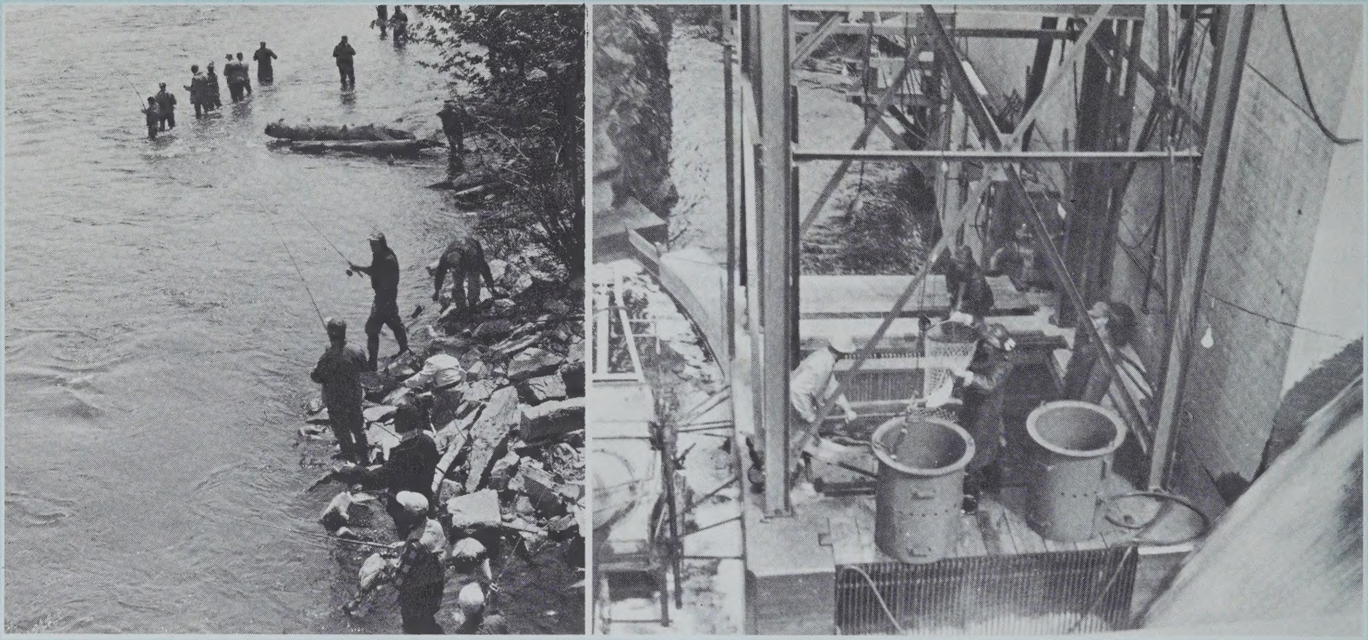
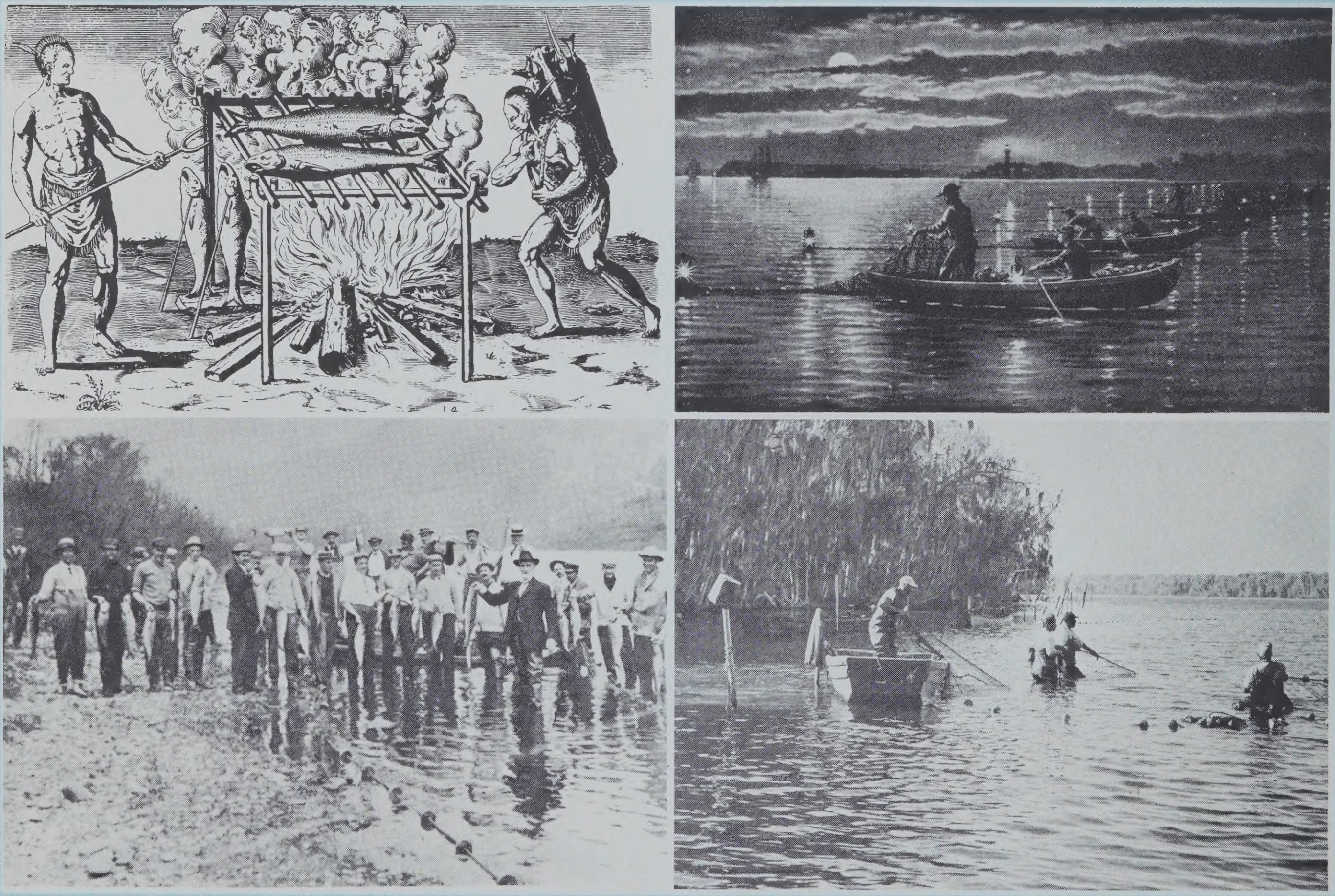
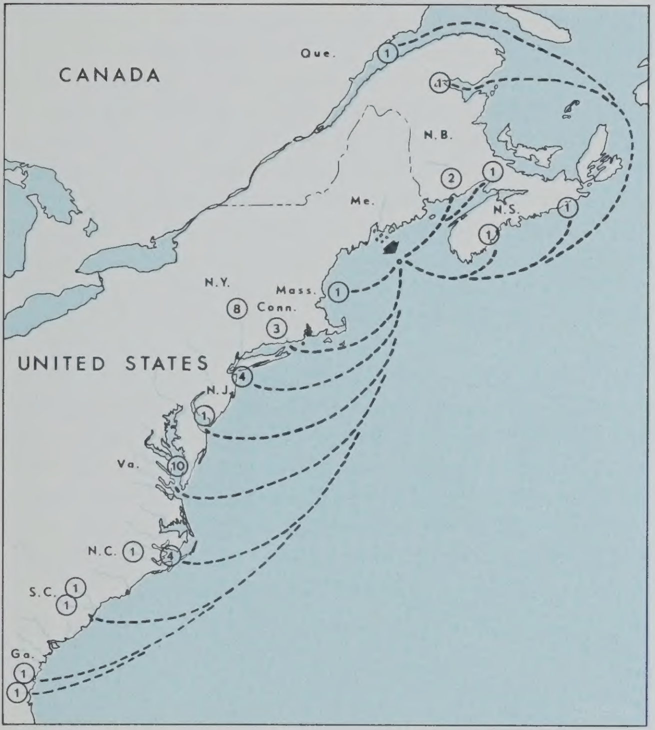


In the Connecticut River, as in many other coastal streams, Shad moving upstream pass anglers (upper left — a scene below the Enfield Dam) and are lifted across barriers (upper right — at South Hadley Falls Dam at Holyoke, Massachusetts). The two middle illustrations — from the *1896 Report of the State Commissioners of Fisheries, Pennsylvania* — show the Indian method of cooking fish and the once active Shad gill net night fishery on the Delaware River. Another scene of former years shows the results of a haul seine made by the Binghamton Shad Club in May 1905 on the upper Delaware River (lower left — photograph courtesy of Mr. Frank Bowen, Hancock, New York). Today (lower right) is much the same — pulling a Shad net on St. Johns River, Florida.

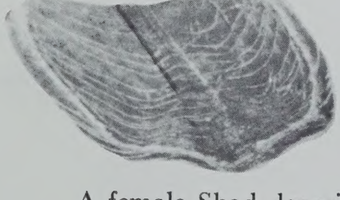


Bay to the Connecticut River migrate northward after spawning and spend the summer and autumn in the Gulf of Maine. Canadian shad also migrate southward to the Gulf of Maine and spend the summer and autumn there. The stocks scatter along the Middle Atlantic in the winter, and as the urge to spawn approaches they move inshore and then migrate either north or south to their native streams and spawn. The cycle is repeated each year the fish escape natural and fishing mortalities.

Tagged American Shad, released in the Gulf of Maine during August-September, have been recaptured in coastal bays and streams from Georgia to Quebec.



Shad mature in 2 to 5 years; males mature usually 1 year earlier than the females. The average life cycle is from 3 to 6 years, but some may live as long as 10 years. Age of the fish is determined by counting the annual growth marks on their scales, as one tells the age of a tree by counting the rings in a cross section.



Magnified projection of a Shad scale.

A female Shad deposits her eggs, from 100,000 to 600,000 depending upon her size and river of origin, in open water where fertilization takes place. The eggs hatch in 3 to 8 days (6 days at 63° F.), depending upon water temperature. The young grow rapidly in fresh water, feeding mainly on insects and crustaceans. Other fishes feed on the eggs and young.

Young Shad leave the streams in autumn when 3 to 5 inches long, probably spend the winter in the Middle Atlantic area, migrate with the adults each summer to the Gulf of Maine where they feed primarily on plankton, and when mature return to spawn in the stream where they were born. In general, the adults are comparatively free from predators other than man.

An Important Food and Game Species

Indians took Shad with bush nets, weirs, spears, and bow and arrows for summer feasts and winter forage for centuries before the white man arrived, and it is conceivable that the early settlers derived their knowledge of Shad-fishing from them. The species early became a staple item of diet because it was easily captured in large numbers and sold for as little as a penny each. The demand increased as towns and cities sprang up. Efforts were made to fish intensively to satisfy this demand for it was believed that the supply was inexhaustible. About 1850, however, the catch began to decline, and this decrease was attributed to overfishing, dams, and pollution.

In an effort to stem the early decline, the U.S. Fish Commission stocked Shad fry and eggs, and States passed stringent laws on fishing. The catch, recorded as early as 1887, increased rapidly and often exceeded 45 million pounds annually until about 1900, after which it steadily declined. Again, the decline was attributed to pollution which rendered rivers unsuitable for the species, overfishing which did not allow enough fish to spawn and replace those taken by the fisheries, and construction of dams which prevented fish from reaching spawning areas.

Today the Shad ranks 40th in relative volume and 28th in relative value of the total U.S. catch by species. The annual Atlantic Coast commercial catch is valued at about $1.5 million, with landings of about 10 million pounds. The Pacific Coast commercial harvest began at low production in 1890 of less than 1 million pounds, climbed to a high of 7 million pounds in 1915, and declined gradually until the 1960's when about 1.5 million pounds were taken annually. The Pacific Coast catch could be increased greatly, if the demand for Shad was larger.

Within the last 2 decades, the species has become highly prized as a game fish in rivers, mainly the Sacramento on the Pacific Coast, and the St. Johns, Connecticut, Delaware, and Pamlico-Tar on the Atlantic Coast. In 1964, the sport catch was about ½ million fish in more than 1 million man-days fishing — anglers in the St. Johns River caught about 125,000 shad and anglers in the Connecticut about 65,000.

Magnitude Only Change in Fisheries

The Shad is taken in the fisheries both in the rivers and along the coast by all forms of gear. The early fisheries used haul seines, weirs, stake and drift gill nets, and dip nets but the seine was the most usual and most efficient method of capture. As the fisheries progressed, the different kinds of gear were adapted to various localities. Improvements were made in techniques of fishing, with economy as an important factor. In the broad estuaries and bays, such as Delaware River and Bay, Chesapeake Bay and tributaries, and Long Island and Albemarle Sounds, mostly pound nets and long rows of stake gill nets were used. In rivers that empty directly into the ocean and generally maintain their flow characteristics to the mouth, such as the Edisto, Ogeechee, and Altamaha Rivers, extensive drift gill net fisheries developed. In most all rivers, because of their narrowness in the headwaters and concentration of fish in spawning grounds, seine, trap, gill net, and extensive bow net and rod and reel fisheries developed. In general, today's Shad fisheries have changed but little from former years except in amount of gear and size of catch.

Research and Management Productive

During the last 2 decades several States and Federal agencies, in particular Maryland, Virginia, and Connecticut, and the Bureau of Commercial Fisheries, have investigated the Shad fisheries of the Atlantic Coast, independently and jointly. The purposes of the studies were to provide basic information for improving the management of the fishery so as to arrest further decline in abundance, and make the knowledge assembled available, so that, through scientific management, the annual yield could be stabilized and probably substantially increased. In the course of the research activities many unknown facts on the life history, abundance, general biology, and factors influencing survival of the species, were made known. Through use of the knowledge assembled, several major Shad populations are now being managed more effectively.

The most effective management procedures involve providing safe passage where the species are blocked from spawning grounds; abating pollution so that fish will survive better and regulating the fisheries by such measures as closed days to reduce fishing effort and limiting the number of fishermen and kinds, amounts, and size of gear to allow more fish to reach the spawning area. So many different regulations govern the fisheries along the coast that local State agencies should be consulted for details. The fisheries in each river are regulated by State and county statute.

Problems, Research and Restoration

Prospects for maintaining productive Shad fisheries and increasing supplies of the species, depend upon reducing pollution, establishing appropriate regulations, minimizing adverse effects of water development on spawning and nursery grounds, and providing fish passage facilities at proposed and existing dams, especially the latter two. Attempts to propagate Shad by means of hatcheries have never been successful, as operated, in increasing natural reproduction. An accelerated pace of water developments for navigation, power, and flood control are making enormous changes in rivers, and Shad are faced with problems that threaten their existence. By rule of thumb "the size of run will be reduced in proportion to the amount of spawning area eliminated, and vice versa". Together with State and Federal agencies the Bureau of Commercial Fisheries is studying whether runs of Shad can be restored in rivers above dams if navigation locks are practical for upstream passage of anadromous fish, whether fish lifts and pool-type fishways are effective for restoring runs of Shad above dams, and what, if any, effects do proposed flood control projects have on the Shad fisheries. Not until we obtain solutions to the problems encountered by the Shad, will we be able to protect and conserve this valuable resource. If the annual yield could be restored to historic levels, it would bring a return to commercial fishermen, at today's prices, of more than $6.5 million, and provide untold number of man-days fishing to anglers.

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Watching Over the Beaver

By
Kent Fuller
UNIVERSITY OF MARYLAND • NATURAL RESOURCES INSTITUTE

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Watching Over

the Beaver

by Kent Fuller

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After a long hiatus, the beaver is reestablishing himself in western Maryland, and nearly everyone is happy to have him back. Furthermore, both the Department of Game and Inland Fish and the University of Maryland's Natural Resources Institute want to make sure he is back to stay. Studies now underway seem to indicate Mr. Beaver has a good chance.

Time was when the beaver ranked first in economic importance of all North American animals. His fur formed the nucleus of the peltry trade, an international commerce of huge proportions. In search of beaver furs, British, French, and Colonial trappers pressed westward across an uncharted continent. Indian and white man shared in the prosperity. Plying the Atlantic Ocean, a stream of sailing vessels transported the hides to European cities where the furs were shorn of guard hairs and converted into wearing apparel. Beaver hats enjoyed the widest popularity, even in the Orient where China offered a lucrative market. John Jacob Astor's fortune was only one of many amassed through the astronomical number of animals harvested.

But whereas the Indian usually trapped only a limited number of beaver in each locality without depleting the reserve, the white man often cleaned out whole areas without regard to the future. This lamentable practice, combined with the clearing of extensive tracts for agricultural purposes, brought the animal to the brink of extinction in the East. Then, as if by providence, the caprices of clothing fashion shifted the vogue in hats from beaver to silk. By the middle 1840's the bottom had dropped out of the beaver pelt market. The pressure was off.

Unfortunately, over harvesting and habitat destruction left their mark. Through the latter decade of the 19th century the beaver population struggled for survival. By 1900 the State of Maryland was devoid of beaver. Almost fifty years passed before the animal began to reestablish himself in our westernmost counties.

In 1960, State Game Department personnel estimated that more than 1,000 beaver inhabited 81 locations in Garrett County. Lesser populations were present in other western counties.

The return of the beaver to Maryland has not been without its problems. Almost any active water course may motivate the beaver to build a lodge and dam. He appears to care little whether the water course is creek, brook, culvert or corn field drainage ditch. Often his pond backs up to flood a farmer's crops or a county road. To add to the difficulties, the beaver has an indiscriminate appetite. He is as content to cut down trees on private estates as on public lands; and when his supply fails, he will satisfy his hunger on a variety of agricultural products.

Naturally, complaints about beaver damage were directed to the State Game Department. To meet the complaints, animals were trapped and removed from problem areas. Many of these animals were set free to establish colonies in other regions of the state.

Nevertheless, as beaver populations increased a more positive plan for population balance seemed to be needed. The Department of Game and Inland Fish thought it advisable to declare a trapping season. The first trapping season, held in 1962 in Garrett County, was restricted to trapping by landowners on their own lands. In 1964 the season was extended to include Allegany County and all citizens were permitted to participate. In 1966, Washington County held its first beaver trapping season.

But there also are favorable aspects in the resurgence of the beaver. In the high country, beaver ponds help maintain the ground water level and reduce the run-off rate in times of heavy rains and snows. In addition, beaver communities create a habitat that is beneficial to many other forms of wildlife.

In the fall of 1962, at the request of the Game and Inland Fish Commission, wildlife biologists at the LaVale station of the Natural Resources Institute launched a broad and continuing research study of the beaver in western Maryland. Both agencies realized that the beaver was well suited to fill a long-vacated ecological niche and could provide a source of income from forest stream areas. Also, the aesthetic appreciation of the animal by local outdoorsmen increased its desirability.

The Institute's program aimed at learning as much as possible about the beaver's life and activities. Workers hoped to make accurate estimates of the size and distribution of the beaver population. These findings in turn would yield information about dispersion patterns and provide clues to the role of geography in the establishment of new colonies by young beaver.

If the trapping season is to continue in western Maryland, it is necessary to know the beaver's reproductive rate. It is also necessary to decide on the most desirable population level within each given range. When these matters have been settled, officials can better control the population by shortening or lengthening the trapping season.

In cooperation with the Department of Game and Inland Fish and private trappers, the Institute's biologists are tabulating and carefully appraising each year's harvest with an eye to predicting the effect the season's catch will have on the next year's population. Records so far show no approach toward overharvesting such as took place in the last century. In fact, preliminary conclusions indicate too few animals are being taken in many areas. As a result, and to avoid overpopulation, the trapping limit was extended to 10 animals per season.

U.S. Department of Interior

The dynamics of beaver populations are intricate and subtle. Laboratory and statistical studies were conducted in other states in the past but data that are sufficiently precise for analytical scrutiny were difficult to obtain. The weak link in the research chain occurs when dealing with live specimens under field conditions. How do you recognize an individual beaver among his fellows? What is his sex? How old is he?

In the early days of the research program, the Institute's biologists confined their laboratory studies to animals caught by commercial and State trappers. The carcasses were turned over to the Institute by cooperating trappers. The information gained through the examination of these carcasses has been invaluable. However, the researchers soon realized that their sampling did not accurately reflect the true nature of the beaver population. Unless a larger sampling was obtained, they felt that their data would lead to erroneous conclusions.

Since then, live trapping by Institute personnel has increased and a considerable body of gross ana-

Natural Resources Institute

Scientists from Maryland University's Natural Resources Institute take measurements of a beaver trapped in western Maryland. Such information is needed to predict trends within the beaver population.

tomical data now exists. Obtaining this data under field conditions can be a dirty, wet and exhausting procedure and the worker always runs the risk of being bitten while taking measurements. To calm the animal during handling, sedative injections are now being employed.

For identification purposes, workers attach a numbered metal disk to the ears of each beaver. To certain beaver, color-coded plastic tags are also affixed. These tags allow the researcher to observe from afar the activity of an individual within the colony.

Determining the sex of a live beaver in the field is very difficult and the researcher cannot always be sure of his findings. When dealing with sexually immature kits, as the young beaver are called, the task is next to impossible. Because existing methods yield such uncertain results, the scientists of the Natural Resources Institute are striving to develop a new and more positive technique; one that can be easily performed in the field. If this proves successful, researchers will possess a tool of great value for studying population behavior.

An abundance of young animals is a reliable index to a healthy, growing population. Thus, the statistical phase of any study requires that ages be assigned as exactly as possible. After trying various mammalian aging techniques, the biologists chose a method in which the teeth of the dead beaver are ground to expose the growth rings. But this is of little value in determining the age of live specimens. Such a method still needs to be developed.

Although this research program is only a few years old, already some patterns of population adjustments are becoming apparent and several conclusions seem justified. The fact that the average age of animals examined so far is less than three and one-half years indicates that the beaver population is on the increase, unchecked by disease and predation and in no danger at present of being overharvested by man.

The beaver's future in western Maryland looks fairly secure.

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Thermal Loading
New Threat to Aquatic Life

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Thermal Loading New Threat to Aquatic Life

By Dr. J. A. Mihursky, Chairman, Department of Environmental Research, University of Maryland

Thermal loading is a relatively new term to pollution biologists. It is even newer to the general public, though it has received considerable attention in recent months—from legislators and industry as well as researchers. Thermal loading is a man-imposed, excess rise in waterway temperature which may gravely threaten aquatic life involved.

Product of Leaping Electricity Need

Although there are many causes of changed temperature regimes in the aquatic habitat—such as irrigation practices, dams, and industrial waste heat—one specific area, the steam electric industry, appears to pose the greatest problem.

Our present method of producing electricity with steam electric stations is a relatively inefficient operation. The potential energy of our fuels is not converted 100 per cent into electrical energy. Energy is lost in the form of heat and must be dissipated. Ideally this waste heat should be released directly into the atmosphere. However, the power industry has found it more economical to use water as a middleman. Large volumes of surface water are pumped into steam electric stations where waste heat is added and finally the heated water is discharged back into a waterway.

In the United States in 1958, 90 billion gallons of water per day were required for cooling purposes by steam generating utilities. Individual installations were generally small, having less than 500 megawatt capacity (1 MW = 1,000 Kilowatts) and required at most a few hundred thousand gallons of water per minute for cooling. At that time the rule-of-thumb judgment was that as population doubled by the year 2010 there would be a quadruple increase in electricity demand.

New estimates in 1965 indicated that electricity demand would increase 32 times by the year 2010. And since then estimates have soared to increases as high as 256 times. It has been predicted that the advent of the electric automobile will automatically double our electricity requirements regardless of where we are on the electricity projection scale. Thus, electricity production may amount to two billion MW by 1980.

If engineering designs remain the same, this production will need 200 billion gallons of cooling water per day. These water requirements amount to one-sixth of the total volume of fresh water that runs off the land mass per day in the United States. Discounting flood flows which occur about one-third of the year and account for two-thirds of runoff, the steam electric station industry will need about half of the total runoff for cooling purposes during the remaining two-thirds of the year. The problem is even greater in certain heavily populated and industrialized northeastern U.S. watersheds such as in Delaware where, due to re-use, over 150 per cent of freshwater flow passes through the various steam electric stations during summer low-flow periods.

Power plants generally increase water temperatures 10-30° Fahrenheit above normal, with discharges commonly reaching 100-115° during summer months. Temperatures of one northeast U.S. river have reached 140° F—a level 40-50° above the tolerance of most aquatic organisms.

Excess Temperature Lethal

Temperature is now known to be an important lethal, directive, and controlling factor in the aquatic habitat. Laboratory experiments have demonstrated that increases of only a few degrees in temperature, especially under summer test conditions, may cause 100 per cent mortality among aquatic animals. Such low tolerance to abnormal summer temperature increases is especially critical to those northern hemisphere animals located near their southern zoogeographic limit of distribution.

The soft shell or Ipswich clam (*Mya arenaria*), for example, is found in shallow shore waters from Labrador to the Virginia-North Carolina border. In the Chesapeake Bay system it is found near its southern limit of distribution on the east coast. Studies have shown that this very important commercial species cannot survive temperatures above those that normally occur in its southern range during hot summer periods. Indeed, recent extensive mortalities of this species in the Chesapeake system appear to have been caused by extended periods of naturally-caused, high, summer water temperatures. Thus in the Chesapeake system we can expect summer mortalities of this eminently edible clam whenever there is artificial heating of its habitat above the normal surface water temperature of about 90° F.

Temperature acts as a directive force in that it influences daily and seasonal behavior patterns. Fishes are well known for their sensitiveness to temperature in influencing their time schedules for migratory movements to spawning grounds. The striped bass *(Roccus saxatilis),* for example, is known to prefer spring temperature in the low 60s for spawning. It is therefore important that highly migratory animals such as striped bass, shad and salmon not be subjected to unusually altered temperatures that would interfere with their normal behavior patterns and consequently interfere with completion of necessary life cycle activities.

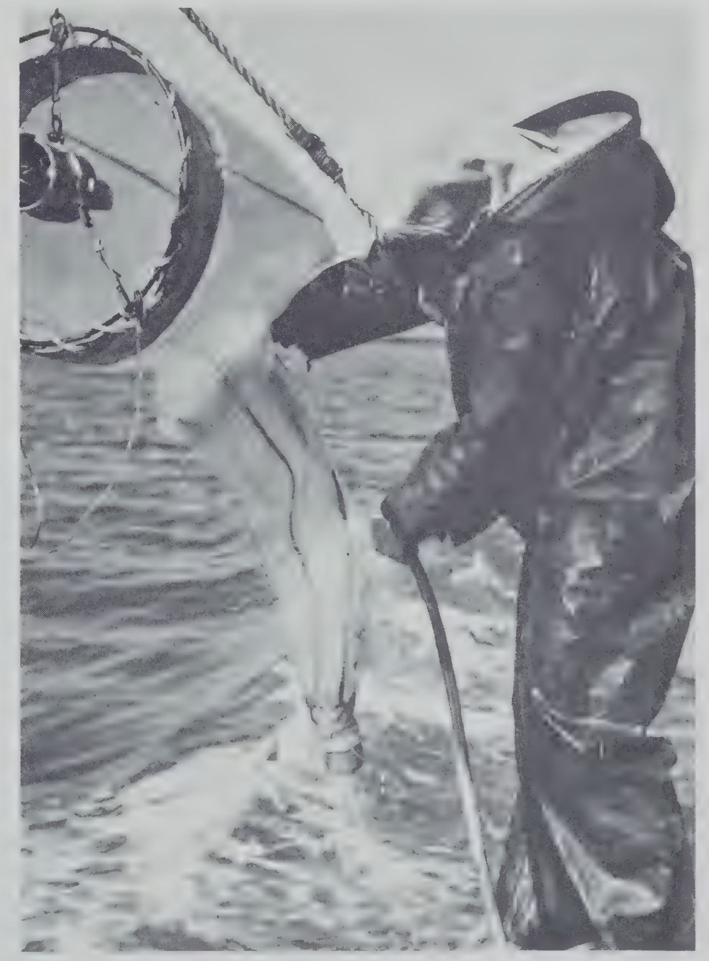
Temperature is a controlling factor in that it affects biochemical reaction rates and consequently influences metabolic rates. As water temperatures are elevated, respiration activity of aquatic animals increases. Unfortunately, dissolved gases become less soluble in water as temperatures increase. Since oxygen requirements of aquatic animals increase with elevated temperatures, there is less oxygen available in the water.

Some environmentalists have been aware for some time of the possible ecological effects of large volumes of artificially heated water on aquatic ecosystems. However, until recent years individual steam electric station installations were relatively small in size and influenced only a small segment of any receiving body of water. So little concern was expressed for these minor environmental "trade offs" with industry. But in the past decade it has become clear that we are in a developing electric age, an age that is intimately tying itself to nuclear energy, an age which promises to give us extensive environmental alterations.

Nuclear Power Adds Problems

Chiefly through the efforts of the United States government and the Atomic Energy Commission, nuclear power has quickly passed from the pilot-plant stage to a position of engineering and economic maturity. Until recently steam electric stations were all coal-fired, oil-fired, or gas-fired installations of less than 1,000 MW capacity. However, since it became clear that the U.S. government was committed to a policy of acceleration of nuclear power development, the electric utility industry has made a commitment to help meet the nation's electricity needs through the use of nuclear energy in large installations.

Nuclear power plants, unfortunately, are even less efficient than fossil fuel plants and, as a result, produce about 50 per cent more waste heat per unit of electricity than fossil



Dr. Mihursky washing a net used in zooplankton studies on an estuary subjected to heated discharges from a steam electric station.

fuel plants. In order to compete economically with fossil fuel, nuclear installations must necessarily be of large capacity.

New nuclear plants will reach 1,000-4,000 MW and, if operated on present engineering designs, each may require up to 7 billion gallons of water per day for cooling. That's more than 20,000 acre feet of water! The need for such huge amounts of water is resulting in power companies wanting to pump volumes nearly equal to the entire flow of a large river.

Oysters Turn Green

Lack of sufficient water from the usual, inland freshwater sources is forcing industry to move to the Great Lakes and to estuarine and ocean sites where large volumes of water and water surfaces are available for cooling.

Unfortunately, brackish and marine water is highly corrosive to metallic surfaces and can cause the loss of heavy metals from power plant condenser tubes to the water. Filter-feeding shellfish such as oysters can absorb certain elements 25,000-70,000 times the concentration level of these elements in the surrounding water. Copper, for example, can reach such high levels in oyster tissues that these oysters turn green and become unfit for human consumption.

Biological growths and deposits on metal walls of heat exchange surfaces, such as condenser tubes, reduce heat exchange capacity and result in loss of electric generating efficiency. In order to keep these surfaces clean of fouling material, the steam electric station industry uses a variety of cleaning agents including detergents, acids, and chlorine. Biologists are becoming increasingly concerned about the use of chlorine since, by design, it is used as biocide, and it not only kills attached organisms but also kills entrained organisms that may be free-swimming or free-floating in the water.

Entrained organisms are especially important to the integrity of estuarine and marine habitats and include a variety of species or life cycle stages such as the following: 1) phytoplankton, the microscopic plant life that is at the base of the food chain; 2) crustacean zooplankton, the herbivores or so-called "cows of the sea" which serve as food for most fish; 3) shellfish eggs and larvae such as those of clams and oysters which have stages that drift in the water for a few weeks before settling to the bottom; 4) fish eggs and larvae.

Studies on phytoplankton and zooplankton have shown destruction of up to 95 per cent upon passage through a steam electric station. If recovery rates of entrained species cannot keep up with the destruction rates, extensive depletions in these species can be expected in the open environment with consequent interference with useful biological productivity.

Thus environmentalists must now contend with possible temperature, metallurgical and biocide problems at each steam electric installation. In addition, nuclear units present still another questionable factor—radioactive materials.

Three Alternatives

Until recently, few states considered temperature change caused by industrial activity to be a pollutant. But the advent of the electric age—with the large growth in electric power demands coupled with engineering moves to add considerable amounts of waste heat to the aquatic environment—has stimulated serious thought about the ecological consequences of these environmental alterations.

The scattered reports existing on the effects of relatively small, coal-fired steam electric stations on aquatic organisms include results that have alarmed some environmentalists because of recorded drastic reduction or complete elimination of normally occurring flora and fauna in heated waters during summer months. Kills of aquatic organisms such as fish, insects, and blue crabs have occurred around steam electric stations during the critical warmer seasons.

In view of the developments cited, we now realize that society faces three alternatives: 1) to ignore the problem and run the risk of adding to our traditional exploitation and sacrifice of natural resources; 2) to produce electricity in a different manner with resultant reduced thermal loads into the aquatic environment; 3) to find ways to redirect thermal loads in a controlled manner and possibly make constructive use of waste heat.

Industry, regulatory and management agencies are now debating which direction to take. Researchers are slowly providing field and laboratory information on temperature effects upon aquatic organisms. Such data will permit useful and definitive predictive statements to be made about the effects of steam electric stations at various sites. But unfortunately the information will not be available before many major decisions are made.

A blue crab killed by thermal loading—one of an estimated 40,000 found around a steam electric station discharge area.

Governmental pressures, through the new federal law requiring states to establish new water quality criteria and standards, are resulting in new temperature regulations being established throughout the United States. Until recently most states had no regulations on thermal discharges. Maryland, one of the few states that did, now recognizes the seasonal temperature requirements of acquatic organisms and has imposed temperature restrictions during all seasons. Significantly, Maryland has reduced allowable maximum summer discharge temperatures from the old 100° F to a maximum of 90° F in tidal waters and 93° F in non-tidal waters. Most states are permitting little if any change in temperature in waters containing trout or salmon populations.

A complication still exists with decisions on nuclear installations. At the federal level the Atomic Energy Commission passes judgment on nuclear plants, specifically on radiological hazards and safeguards. It has been given no responsibilities regarding thermal wastes and is requesting the U.S. Fish and Wildlife Service and the Federal Water Pollution Control Administration to make recommendations to assist in evaluating proposed thermal discharges. New legislation is necessary to clarify the authority of the various governmental agencies.

In February (1968) Senator Muskie's Senate Subcommittee on Air and Water Pollution started holding hearings on thermal pollution problems throughout the country. Facts are being brought into the open and such subjects as environmental effects, engineering designs, cost benefits and site selection are being thoroughly discussed.

Present alternatives in engineering designs include the use of evaporation cooling towers in open cooling systems. Water is dropped down the inside of a tower and air convection passing up from the tower base reduces the water temperature. This technique is commonly used in England where relatively low air temperatures make such a system very practical. Unfortunately evaporation may cause a 10-20 per cent loss of water to the atmosphere. Thus water is removed and made unavailable for other purposes; indeed such evaporation tends to concentrate other pollutants in the water.

From the environmentalist's viewpoint a closed-circuit cooling system similar to an automobile radiator is ideal for minimizing environmental effects. Closed-circuit devices work with electric powered fans and will consequently consume a small percentage (about 3 per cent) of a steam electric station's electricity production. Industry contends that cooling devices are too expensive to operate and would prefer to avoid incorporating such design changes into their engineering plans.

Recommendations

At a recent Senate Subcommittee hearing the author recommended the following:

1) Considerably more basic research is needed on the effects of temperature and temperature change on all life-cycle stages of our important aquatic species. Temperature effects on mortality, behavior, and physiological activity are not presently available in sufficient quantity or quality to make definitive predictive statements about steam electric station effects at all proposed sites.

2) Alternative methods of cooling should be explored.

3) Alternative sources of water for cooling purposes should be evaluated.

4) Chlorine, used to clean condenser tubes of steam electric stations, acts as a biocide and its use should be prevented. Other less harmful cleaning methods should be required.

5) Since certain commercially important shellfish can concentrate heavy metals in their body tissues and be rendered unfit for human consumption, adequate safeguards should be required to prevent metallurgical problems and the consequent release of heavy metals to aquatic systems.

6) If large volumes of cooling water are to be used, site selection is a critical operation and environmental cost-benefits should be taken into account.

7) Power utilities should not be permitted to operate independently in site selection; permits for land acquisition, construction, and water use should not be given until a responsible State or Federal agency has approved the site and operational procedures as optimal to the public welfare.

8) Power utilities should bear the cost of investigational work necessary for site and environmental evaluations.

9) Ecological evaluations should be carried out only by responsible individuals or agencies approved by the controlling State or Federal agency.

10) The regional development of steam electric stations should not conflict with large-scale regional socio-economic planning.

11) Possible constructive uses of waste heat should be thoroughly explored, with a pilot-plant operation as a first step.

It is apparent that there is a growing awareness of the environmental consequences of man's progress. We are developing a better attitude toward our habitat and many now realize that we need a quality environment to have a quality society. Unfortunately, the march of civilization—with its present great growth in population, heavy demands for material items and services, increase in technological capacity and concurrent increase in waste materials—threatens to inundate us before effective controls are developed.

We are experiencing more far-reaching radical environmental alterations as a result of man's activities during this century than has occurred in the entire human history. Our primary responsibility, as the most dynamic species endowed with the ability to reason that has yet evolved on this "organism", Earth, is quite clear. We must determine whether the rapid growth and change characteristics are creating a stress environment that exceeds quality living limits. If they are, we must learn to cope with them right now or it will be a sorry legacy that we pass on to future generations.

Dr. Joseph A. Mihursky

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